vaccination followed by a booster vaccination within 2 to 3 weeks, maximum protection will not be achieved without the booster vaccination. Essentially, the money spent for the first injection is wasted. The second problem, lack of frequent vaccinations, is seen especially with leptospiral vaccines. Leptospiral vaccines should be administered every 6 months to achieve adequate protection. It is also important for heifers to start receiving leptospiral vaccinations at 6 months of age so that they have received two vaccinations by the time they are used for breeding.

Conclusions

Health management of replacements requires attention to many different areas, ranging from nutrition and management of late lactation and dry cows to vaccinations of replacements. Health management of replacements is an area that is often overlooked because producers do not see an immediate return on their efforts and prefer to spend their time improving management of the milking herd. For health management of replacements, however, the old saying that "an ounce of prevention is worth a pound of cure" really holds true.

See also: **Body Condition**: Effects on Health, Milk Production and Reproduction. **Colostrum**. **Diseases of Dairy Animals, Infectious**: Leptospirosis; Johne's Disease. **Diseases of Dairy Animals, Non-Infectious**: Acidosis/laminitis. **Ration Formulation**: Dry Period and Transition Rations in Cattle; Lactation Rations in Cattle. **Replacement Management, Cattle**: Preruminant Diets and Weaning Practices; Growth Diets.

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Breeding Standards and Pregnancy Management

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Introduction

Replacement heifers represent the future of the dairy herd. Herd turnover occurs about every 3 to 4 years. Or, in other words, this rate of turnover translates into an annual culling rate of 25–33% necessitating a supply of herd replacements in the form of heifers. These rather high culling rates produce a significant drain on income because the dairy producer loses in milk income (the cull generally produces more milk than her younger replacement), funds expended to purchase the replacement, and also may lose on the value of the calf born to the replacement depending on its genetic merit. In other words, the cost of a replacement heifer equals her purchase cost or value (if raised on the farm) plus the losses in milk yield (difference in the greater value of the milk from the cow and her replacement for what would be the remainder of the cull cow's lactation) minus the recovery value of the cull (sale price of a cull). As a result, the recovery value of the cull when sold is only about one-third to one-half the cost of purchasing her replacement. The time-sensitive nature of establishing pregnancy in dairy heifers dictates that excellent management inputs are required including the use of various hormones to manipulate the oestrus cycle to achieve pregnancy.

Value of Replacements

Rearing and mating of replacement heifers is a critical step in the survival of the dairy farm because it represents 15–20% of total farm costs. Age at first calving is the single most important variable influencing the costs of raising heifers. Age at first calving could be defined as total days on feed since birth and is a function of the rate at which mating weight (age) and conception is achieved. Once pregnancy is established, total days on feed become fixed. Costs associated with age at first calving include feed, labour, housing, interest on investment, mating and veterinary health, and death loss. To reduce the costs associated with rearing heifers, one must reduce age at first calving or reduce feed costs because they represent approximately 60% of total rearing costs. Reducing age at first calving is more easily achieved because finding significant savings on low-cost feeds is unlikely given their lack of universal availability to most producers. In a recent survey, the average cost to raise a home-grown heifer was just US$100 more than if the heifer was raised on a custom heifer-rearing operation.

Age at First Calving

The age at first calving is recommended to be at or about 24 months of age. Both lifetime yield and profitability data support this age at first calving. However, an evaluation of 6 million US dairy cow records from 1960 to 1982 found no appreciable change in calving age for any of six dairy breeds. Mean ages (months) at first calving for 1960 and 1982 were: Ayrshire, 28.4, 28.6; Brown Swiss, 28.2, 27.8; Guernsey, 27.6, 27.4; Holstein, 27.3, 27.8; Dairy Shorthorn, 27.7, 27.8; and Jersey, 26.0, 25.9 months.

Age at puberty is generally not considered to be a limiting factor in age at first conception and thus age at first calving. Most dairy breeds achieve puberty by 11–12 months of age or sooner as long as they are fed according to National Research Council (NRC) standards for energy, protein, fibre, minerals and vitamins. The NRC recommendations are an accepted minimum standard. Research based on the former 1989 standards showed that when all nutrient requirements were increased by 15%, heifers grew more adequately and produced more milk in their lifetime than those fed at the NRC standard rates. Age, but not body weight, at puberty was reduced by 3 weeks in those fed at the 115% standard. Most studies conclude that optimal age at calving to maximize lifetime performance is 23 months, whereas optimal profit was achieved at first calving ages of 25 months. Attempts to reduce age at first calving should avoid having heifers calving at less than 22 months of age. Heifers calving at younger ages (<22 months) are more likely to experience dystocia and are subsequently three to four times more likely to have a retained placenta, metritis or reduced reproductive efficiency, and to be culled from the herd. In addition, first lactation yields may be lower.

As indicated above, despite all of this information, age at first calving has changed but little since 1960. Reasons for this inaction include inattention by dairy producers to age of heifers and lack of understanding of the importance of heifer management to overall cost benefits.

Breeding Standards

Well-grown dairy heifers should reach puberty by 11 to 12 months of age as indicated by the regular occurrence of oestrus (*see* **Oestrus Cycles**: Puberty). When heifers first stand to be mounted from the rear by another female, this begins the period of oestrus and a new (or first) oestrus cycle (*see* **Oestrus Cycles**: Characteristics). The period of oestrus is about 10 to 18 hours in duration and begins each new oestrus cycle (day 0 of the cycle). About 90% of cycling heifers show a slightly bloody discharge (bloody tail or metoestrual bleeding) from the vulva 1 to 2 days after oestrus whether or not they were inseminated or have conceived. This is a sign that they were in oestrus. The oestrus cycle is about 21 days in duration and normally ranges from 18 to 24 days. Cycles shorter than 18 days may occur in heifers after they experience their first oestrus at puberty. The oestrus cycle is cyclic because in the absence of fertile mating or artificial insemination (AI) during oestrus, a new oestrus will occur in approximately 3 weeks.

During normal oestrus cycles, the heifer comes into oestrus and ovulates an egg about 24–32 h after the beginning of oestrus. At the site of ovulation, the empty follicle that ruptured to bring forth the egg transforms into a corpus luteum. The corpus luteum produces progesterone necessary to prepare the uterus for a potential pregnancy. In the absence of a viable embryo at about day 16 to 17 of the 21-day cycle, the corpus luteum dies or regresses (this process is known as luteolysis); otherwise, the embryo helps to preserve the corpus luteum to allow pregnancy to continue. Prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) is secreted by the uterus to cause death of the corpus luteum (luteolysis) around day 18 of the cycle in the absence of a viable embryo. As the corpus luteum regresses, new ovarian follicles begin to grow and mature, one of which will be selected to ovulate just after the heifer goes out of oestrus, producing the egg that potentially will form a new calf upon fertilization. Thus, the cyclic nature of the oestrus cycle continues, only to be interrupted by pregnancy.

The recommended age to begin a breeding programme with heifers is about 13 to 14 months, provided the heifers are adequately grown and cycling. The recommended body weights at first insemination of replacement heifers are summarized in Table 1. If heifers are mated too young and(or) before adequate growth occurs, their first lactation yields will be compromised. Furthermore, overconditioned (fat) heifers do not reproduce well and will not produce milk to their genetic potential. Waiting to breed heifers when older than 14 to 15 months fails to result in more milk production in their lifetime. Inseminating heifers at 13 to 14 months of age allows for pregnancy to become established at 14 to 15 months of age and for most replacements to calve by 2 years of age. It is important that heifers calve at or near 2 years of age to reduce their rearing costs by producing milk at an earlier age as discussed above. First-service conception rates (pregnancy) should range from 50% to 70% in heifers. About 5% of heifers eventually fail to conceive for various reasons and must be culled.

Management of Breeding

With tools readily available today for management of the oestrous cycle, no excuse exists for failing to achieve timely pregnancies in the replacement herd. Prior to 1980, no hormonal products were available to synchronize oestrus and ovulation in heifers. Therefore, breeding of heifers was wholly dependent on visually detecting oestrus prior to AI. Today, various products include orally active (feed additive) or intravaginally placed progestins, gonadotrophin-releasing hormone (GnRH) and $PGF_{2\alpha}$. Managing the oestrus cycle to the convenience of the breeder is now possible even in large heifer developer operations where replacements are raised on contract for individual dairy producers or are raised for sale to other producers.

Feeding melengoestrol acetate (MGA) (0.5 mg day^{-1} per heifer) for 14 days synchronizes oestrus (see (1) in Figure 1). Depending on the stage of the oestrous cycle in which any heifer begins the MGA feeding period, few have a functional corpus luteum after 14 days of feeding. Most heifers show oestrus within 2 to 6 days after withdrawing MGA from the feed. This oestrus is quite infertile in those heifers that began MGA feeding after day 10 of the cycle. Because the identity of the less fertile heifers is unknown, this first oestrus is passed over and heifers are given an injection of $PGF_{2\alpha}$ 17–19 days after MGA withdrawal. Insemination of heifers based on detected oestrus usually occurs between 2 and 5 days after $PGF_{2\alpha}$. An option of inseminating any noninseminated heifers at 72 h after $PGF_{2\alpha}$ is possible

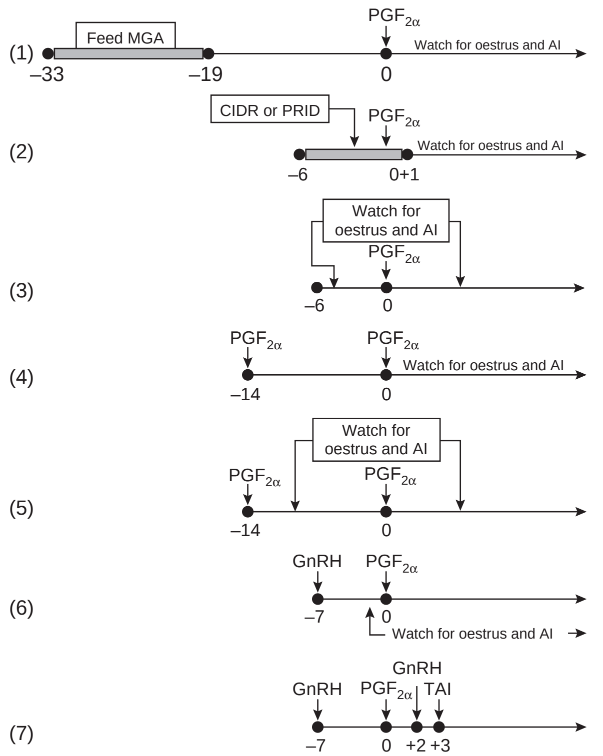

Figure 1 Seven programmes for synchronization of oestrus or ovulation are illustrated in dairy heifer replacements. (1) Feeding of melengoestrol acetate (MGA) for 14 days and passing over the oestrus expressed upon MGA withdrawal followed by an injection of $PGF_{2\alpha}$ given 17–19 days after MGA; (2) intravaginal insertion of a progesterone-releasing insert (progesterone-releasing intravaginal device, PRID; controlled internal drug release, CIDR) for 7 days with $PGF_{2\alpha}$ injection administered at or one day before insert removal; (3) visual detection of oestrus for 6 days prior to injecting all noninseminated heifers with $PGF_{2\alpha}$ on the 7th day; (4) two injections of $PGF_{2\alpha}$ given 14 days apart with inseminations occurring after the second injection or (5) after both injections; (6) an injection of gonadotrophin-releasing hormone (GnRH) 7 days before an injection of $PGF_{2\alpha}$; and (7) same as (6) but a second injection of GnRH is given 48 h after $PGF_{2\alpha}$ with one timed AI 12–20 h later.

but conception rates will be approximately 60–75% of those achieved based on observed oestrus.

Insertion of a progesterone-impregnated intravaginal insert (progesterone-releasing intravaginal device (PRID) or controlled internal drug release (CIDR) insert) in addition to $PGF_{2\alpha}$ effectively synchronizes oestrus in a short-term, 7-day period (see (2) in Figure 1) (*see* **Oestrus Cycles, Control**: Synchronization of Oestrus). Injection of $PGF_{2\alpha}$ lyses any functional corpus luteum 24 h prior to removal of the insert. Generally, inseminations occur after detected oestrus during a 2–5-day period after its removal. One also can inject $PGF_{2\alpha}$ at the same time the insert is removed. In this case, oestrus will be delayed by approximately 12–24 h and more variable in its range of occurrence. A more simple and less expensive method (see (3) in Figure 1) includes detection of oestrus during 6 days and then inseminating any oestrual heifers according to signs of oestrus. On the 7th day, $PGF_{2\alpha}$ is injected in any noninseminated heifer to induce luteolysis and oestrus for subsequent insemination. The success of this method depends on the accuracy and efficiency of visual detection of oestrus. A more complicated method involves giving two injections of $PGF_{2\alpha}$ 14 days apart. One can only inseminate oestrus-detected heifers after the second of two injections (see (4) in Figure 1) or inseminate after both injections (see (5) in Figure 1) and reduce the number of second injections to all noninseminated heifers. Timing of inseminations without regard to detected oestrus at 72–80 h after $PGF_{2\alpha}$ produces lower conception rates than with inseminations made after detected oestrus.

A newer technique (see (6) in Figure 1) combines GnRH to induce release of follicle-stimulating (FSH) and luteinizing hormones (LH) plus injection of $PGF_{2\alpha}$ 7 days later prior to visually detected oestrus. The GnRH injection in some heifers better controls follicular development and synchronizes it with luteolysis that follows $PGF_{2\alpha}$. About 10% of heifers show oestrus within 24 h of $PGF_{2\alpha}$, and therefore, for optimal results detection of oestrus should begin 24–48 h before $PGF_{2\alpha}$.

An alternative (*see* (7) in Figure 1) to the previous method allows for a single timed AI (TAI) after the injection of $PGF_{2\alpha}$ (*see* **Oestrus Cycles, Control**: Synchronization of Ovulation and Insemination). One gives a second injection of GnRH to all heifers at about 48 h after $PGF_{2\alpha}$ and then inseminates about 12–20 h later without regard to visually detected oestrus. Of course, if oestrus is observed prior to $PGF_{2\alpha}$ or the second GnRH injection, one inseminates the heifer based on visual signs and discontinues the remainder of the injections.

All of these programmes only synchronize oestrus for the first AI. However, subsequent periods of oestrous are quite well synchronized in those heifers that fail to conceive to the first AI. Use of tail chalk or tail paint, heat mount detectors, or more sophisticated electronic devices can be used to detect oestrus prior to any subsequent insemination (*see* **Mating Management**: Detection of Oestrus). Because heifers tend to display very pronounced signs of oestrus, they are easily detected if consistent twice-daily periods of visual observation are carried out.

Early detection of pregnancy allows for identifying those heifers that are not pregnant so prompt reinsemination can occur. Pregnancy can be accurately determined by transrectal ultrasonography as early as day 28 in heifers or by palpation of the uterus and its contents by days 35–40 (*see* **Mating Management**: Fertility). The objective of this diagnosis is to find nonpregnant heifers so they can be treated promptly to induce a new fertile oestrus. The treatments utilized on nonpregnant heifers can include any of those short-term methods described above. Historically, when palpation occurs, the heifer is given an injection of $PGF_{2\alpha}$ when a functional corpus luteum is palpated on the ovary and subsequent behaviour is monitored for visual signs of oestrus. When oestrus synchronization is performed before first AI, the day of oestrus generally is known when palpation occurs. If palpation occurs at 35 days after AI, one is generally correct in assuming an oestrus was not detected at 20–21 days and the heifer is on cycle days 14–15 when pregnancy diagnosis occurs. This is an ideal time to give $PGF_{2\alpha}$ to induce a fertile oestrus. Given the nearly equal cost of palpation and a $PGF_{2\alpha}$ injection, any nonpregnant heifer generally is given $PGF_{2\alpha}$ and observed for subsequent signs of oestrus. Injections of $PGF_{2\alpha}$ cause abortion in pregnant heifers so caution is warranted.

Management of Pregnancy

Once pregnant, replacements should not be forgotten and allocated to pasture or other areas without observation. Some embryonic and foetal losses occur after conception. It is recommended to reconfirm pregnancy after 90–100 days of pregnancy to preclude maintaining an open replacement until she is found not pregnant at her projected calving date.

Pregnant heifers should continue to grow at NRC recommended rates to achieve adequate size by calving time. Depending on the breed, daily gains of 0.45–0.75 kg are usually adequate to achieve desired first calving weights. Recommended precalving body weights (compared to those at maturity) are summarized in Table 1.

Table 1 Recommended body weights (kg) of dairy heifers at first insemination and first calving

Breed	*First mating weight*[a]	*Precalving weight*	*Mature body weight*[b]
Ayrshire	325–340	450–475	545
Brown Swiss	360–400	545–565	680
Guernsey	325–340	450–475	520
Holstein	360–400	545–565	680
Jersey	285–295	360–385	410

[a] From Taylor RE (1992) *Scientific Farm Animal Production*, 4th edn, p. 402. New York: Macmillan.
[b] From Classification Score Card, Purebred Dairy Breed Association.

Precautions to prevent disease and injury to gestating heifers are important. Adequate shade during hot months of the year prevents low birth weights and subsequent poor milk yield and reproductive performance after calving. Further, adequate shelter to eliminate wind chill during cold months minimizes frostbite to teats when udder and tissue oedema occur during late gestation. Immunizations before first mating and again between 50 and 60 days before expected parturition for prevention of infectious bovine rhinotracheitis, parainfluenza, bovine viral diarrhoea, bovine respiratory syncytial virus, *Clostridium* spp., leptospirosis (five way) and calf scour pathogens (*Escherichia coli*, *Clostridium perfringens* (type C) rota and corona virus) are recommended. Reimmunization against calf scour pathogens should occur at 3 weeks precalving. Depending on location of heifers (pasture versus concrete confinement facilities), dewormers (to prevent gastrointestinal roundworms) should be administered at or near calving.

Parturition

Other than for various traits including milk yield, milk components, and physical type traits, sire selection for heifers is critical for what occurs at calving. It is recommended to choose sires for heifers that are known to be calving-ease sires. The US Department of Agriculture produces quarterly sire summaries with calving ease information on all sires whose semen is available for purchase from semen-producing organizations or bull studs. The information on calving ease is based on reported calvings of other heifers whose mates were the sires summarized. The information reported is the percentage of births to heifers that were associated with difficulty calvings, based on a scale of 1 to 5, reported by observers attending calvings. Calving difficulty scores assigned at calving range from 1 to 5 (1, no assistance; 2, slight problem; 3, needed assistance; 4, considerable force; 5, extreme difficulty). The calving-ease percentage reported for each sire is that percentage of births to heifers when the calving difficulty scores were 4 or 5. In the Holstein breed, the average calving-ease percentage is about 9%. One should use sires with calving-ease percentages that are at least less than average while not compromising selection for excellent production traits of sires.

Assistance at calving time is recommended for heifers. They should be observed frequently as due dates approach. Calving areas should be clean, free of hazards, provide good footing, spacious to allow the heifer to move about and position herself without pinning herself against an obstruction in the calving area in which the calf has no room to be delivered. When assistance is required for a large calf, twins or breech births, arms, hands and instruments should be sanitized. Plenty of lubricant should be used. When a calf jack or obstetrical chains are used, one should only pull when the abdominal muscles of the mother contract, therefore, working with her contractions. Applying too much force can tear the heifer and damage the calf.

The absolutely most important measure and end point of successful reproduction is survival of the calf at birth and at various intervals thereafter. Immediately after birth, proper management of the newborn is critical to its survival. This includes colostrum feeding immediately after birth, immunizations, navel-dipping to prevent navel invasion of microorganisms, etc.

Conclusions

Because replacement heifers represent the future genetic investment of any dairy herd, their management is critical to herd survival and longevity. Associated costs and investments in replacements are significant at 15–20% of all farm costs. Timeliness of establishing pregnancy is significantly improved when using various hormonal schemes to programme the oestrus cycle to facilitate the use of AI and ensure a greater proportion of heifers calve by 24 months of age. Sire selection should emphasize production traits and calving ease to maintain high production but facilitate fewer problems at first parturition. Because heifers are more fertile than their lactating counterparts, the best sires can be used with a much greater cost–benefit ratio.

See also: **Mating Management**: Detection of Oestrus; Fertility. **Oestrus Cycles**: Puberty; Characteristics. **Oestrus Cycles, Control**: Synchronization of Oestrus; Synchronization of Ovulation and Insemination.

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Reproduction *see* **Gamete and Embryo Technology**: Artificial Insemination; Multiple Ovulation and Embryo Transfer; *In Vitro* Fertilization; Cloning; Transgenic Animals; Sexed Offspring. **Goat Husbandry**: Reproductive Management. **Mating Management**: Detection of Oestrus; Artificial Insemination, Utilization; Fertility. **Oestrus Cycles**: Puberty; Characteristics; Postpartum Cyclicity; Seasonal Breeders. **Oestrus Cycles, Control**: Synchronization of Oestrus; Synchronization of Ovulation and Insemination. **Pregnancy**: Characteristics; Physiology; Parturition; Periparturient Disorders. **Sheep Husbandry**: Reproductive Management.

Retinol and Carotenes *see* **Vitamins**: Vitamin A, Nutritional Significance.

Reverse Osmosis *see* **Membrane Separation**.

RHEOLOGY OF MILK AND DAIRY PRODUCTS

Contents

Principles and Significance in Assessing Rheological and Texture Properties

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Introduction

Rheological and/or texture properties of foods are part of the physical properties of food materials which may be characterized or quantified by means of physical methods, and which are important for, e.g., product handling, processing or consumer acceptance. Usually, the term 'texture' is used in a very